[redacted]

February 8, 1971

To: John C.

25X1 From: [redacted]

Subject: Quarterly Technical Progress Report No. 3
25X1 Contract No. [redacted]

25X1 Reference: [redacted] 2201201-QTR-3

This is the third quarterly technical progress report Contract No. [redacted] covering the program effort from 20 October 1970 to 19 January 1971. This report reviews accomplishments of this program conducted both at the [redacted] facility in [redacted] and at the customer's facility.

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INTRODUCTION

During this quarter the most significant accomplishment of this program occured with the extraction of very low contrast information from operational material that was otherwise below visual threshold for conventional optical systems. This demonstrated one of the characteristics of the optical high frequency enhancement technique. However the system function is demonstrated with all low contrast imagery by its contrast enhancement at high frequencies even though no new detail is discovered. A large series of processed results obtained during the past quarter with low contrast imagery illustrate the gain that can be obtained.

Applications during this quarter also include initial investigations of the phase relief component of imagery on film for increased information extraction capability, and the initiation of sponsor lab fabrication of complex filters for coherent image manipulation such as defocus or image blur compensation. These areas are discussed below.

During the past quarter 11 trips were conducted to the sponsor facility for program effort. At this time we are scheduling an average 2-1/2 days per week at the laboratory. Objectives at the lab include continued evaluation and application of OIM to operational material, measurement of OIM systems frequency response and correlation with analytical prediction, and initiation of coherent OIM processes.

PHASE RELIEF IMAGE EVALUATION

During the past month a series of experiments have been conducted to determine how the photographic phase relief image might be used to advantage in optical image manipulation procedures. Transparencies were bleached using a non-tanning bleach in order to isolate the phase distribution while maintaining as much fidelity as possible. The bleached transparencies (phase objects) were then viewed with a coherent optical system using three standard techniques. The three techniques evaluated were:

(1) the Schlieren technique
(2) the central dark ground method, and
(3) the phase contrast method (modified).

The Schlieren technique consists of placing a knife edge in the frequency plane (Fraunhofer plane) such that one half of the spectrum is blocked. Tonal range can be altered in the image by changing the position of the knife edge relative to the dc or undiffracted light. This technique, in general, results in edge enhancement producing an image intensity distribution which is proportional to the derivative of the phase distribution for small phases.

The central dark ground method consists of placing an attenuating filter over the dc or undiffracted light, therefore reducing the effect of the background light and allowing the viewing of the phase image. Appearance of the image depends upon the transmission of the attenuating filter and to a lesser extent upon its size.

The modified phase contrast method consisted of placing phase plates over the dc changing the phase of the background light relative to the diffracted light rendering the phase image observable. For small phase and phase plates of $\pi/2$ or $3\pi/2$ this technique produces an image intensity distribution proportional to the phase object. Filters are now being prepared having correct values for both positive $\pi/2$ and negative $3\pi/2$ phase contrast observation.

Attemps at combining the usual density object (amplitude object with respect to the coherent optical system) and the phase object to obtain a better output image has thus far proved unsuccessful. This is apparently due to the introduction of significant amounts of noise when the object transparency is not placed in a fluid gate. Fluid gating of the object transparency of course eliminates the major portion of the phase object distribution. Indications are that phase imagery might prove useful as a mensuration tool due to the distinct sharp edges which are often observed. It should be remembered that the phase distribution is considered to be linearily related to the desnity or mass of silver removed rather than to the transmittance of the transparency and therefore the interaction of these non-linearily related images (amplitude and phase) should not necessarily be expected to result in an overall "better" image.

PHASE FILTER GENERATION

The phase portion of a complex spatial filter is generated from a density image that is recorded on a Kodak High Resolution Plate. Since the phase shift is a function of the recorded density and the bleaching process, very careful sensitometry has to be performed. The steps involved for repeatability are as follows:

A. Development of the exposed High Resolution Plate (HRP)
   1. Open tray development in D-76 made with distilled water for 5 min. Agitate first 30 sec and 5 sec each 15 sec thereafter.
   2. Wash in running water for 30 sec.
   3. Rapid fix for 3 min.
   4. Wash in running water for 5 min.
   5. Dry at room temperature.
   6. Read the density.

   A Kodak OC(light amber) safelight filter may be used in steps 1-3 and room lights for steps 4 and 5.

B. Bleaching the density image

   The bleach is made with the following Kodak chemicals:

   500 ml of distilled wate at 100°F
   19 g of Potassium Dichromate
   28 g of Potassium Bromide
   19 g of Potassium Ferricyanide
   5 ml of Acetic Acid
   Distilled water to make 1000 ml.

   Process the HRP as follows
   1. Bleach for 4 min.
      Agitate first 30 sec and 5 sec each 30 sec.
   2. Wash for 30 sec in running water.
   3. Clear bath for 1 min in Kodak Clearing Bath for Direct Positive Paper.

4. Wash for 1 min in running water.
5. Rapid Fix for 3 min.
6. Wash for 1 min in running water.
7. Hypo Clearing Agent for 2 min.
8. Wash for 2 min in running water.
9. Photo-Flo for 30 sec.
10. Dry at room temperature.
    A Kodak OC (light amber) safelight filter may be used for steps 1-5 and room lights for 6-9.

The D-76, Rapid Fix, clear bath and Hypo Clearing Agent are all used in open trays at a half inch depth and at 68°F. These chemicals may be reused for a one day period only. The bleach should be stored and used in a rubber tank and may be reused for two or three months.

PROCEDURE FOR FABRICATING A PHASE COMPONENT WITH KODAK HIGH RESOLUTION PLATES

The phase shift on High Resolution Plates (HRP) is directly related to the density on the plate if all the steps in the phase plate development are closly followed.

A general procedure for finding the phase shift associated with a given density is as follows:

1. Expose a Kodak or similar photographic step tablet onto a HRP.
2. Develop the plate using the phase plate development procedure.
3. Trace the density steps on a calibrated microdensitometer so that the density of each step may be tabulated.
4. Bleach the plate using the process outlined.
5. Measure the phase shift of each of the bleached steps with the use of a Mach-Zehnder interferometer.
    a. Set the plate in the object plane of the interferometer.

b. Focus the object in the image plane and set the frequency of the fringes so that there are at least eight fringes across each phase step.

c. Photograph the image on Kodak Pan X or other high resolution film.

d. Make 8" x 10" prints of the interferograms.

e. Measure the shift of the fringes from the 8" x 10" prints. This will be the phase shift for the measured density and the wavelength of light used in the interferometer. For other wavelengths use the relationship

$$\delta_t = (\delta_{measurement}) \frac{\lambda \text{ interferometer}}{\lambda_{new}}$$

6. A phase vs. density curve can now be plotted for HRP at any wavelength of light that is needed.

The curve generated from step 6 is only good for controlled development. Since people agitate the chemicals differently a new curve should be generated for each person working with phase control.

MAKING PLATE OF A GIVEN CONFIGURATION

There are many methods of generating phase plates of a given configuration. The method below has been used with good success for binary functions.

1. Calculate the configuration needed including dimension.
2. Make a scaled up master of this configuration on Stabilene Film, Cut'N'Strip Film Surface made by Keuffel & Esser Co. The scale used will depend on the size of an evenly illuminated light source that is available for reduction. An Aristo grid source is a good, evenly illuminated light source for this type of work.

3. Reduce the master onto a 2" x 2" HRP at about 50% of the scale used in step two. This will be the new master plate for further reductions.
4. Make a reduction to the needed scale with the use of the Aristo or photographic enlarger.
5. The density of this plate should be measured on a microdensitometer and compared to the density needed for the specified phase shift. If the density is correct the plate may be processed by bleaching etc. The bleached plate may than be measured on the interferometer as a further check.

WORK BEING PERFORMED WITH COMPLEX SPATIAL FILTERS AT [redacted]

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There are many photographs taken where non-ideal conditions exist, and as a result much high frequency information is lost. This information in some cases may be retrieved with the use of complex spatial filters. This part of the program is directed to look at defocused and motion blurred photographs with the use of complex filters and a microscope as the playback system.

COMPLEX FILTERS

Presently, complex filters have been made for correcting defocused imagery. These filters will correct images that have been defocused five wavelengths using an f/4, spherical lens system with incoherent light. The next step will be to make filters for correcting imagery that has been degraded due to image motion.

TEST IMAGERY

Defocused three bar resolution targets have been made to test the optical playback system and the filters that have been fabricated. The first set of targets were made for the defocused filter of five wavelengths and a playback transform lens of 32mm, the 4X microscope objective. This imagery was first recorded in a defocused mode on type 3404 film It was then contact printed onto type 2430 film. This yeilds a realistic sample of the film used in reconnaissance systems.

RECONSTRUCTION SYSTEM

The reconstruction system is a basic microscope with two changes. One change is the illuminating source. A mercury arc source with a collimator to introduce partially coherent light into the system is used as the microscope illuminator. The second change is the introduction of the complex filter into the transform plane of the microscope. The location of this filter is 32 mm behind the microscope objective.

INITIAL RESULTS

The first results have been obtained using the above system for defocusing. The resolution of the three bar target is 13ℓ/mm when defocused 5 wavelengths in an f/4 system. Reconstructed imagery shows a resolution limit of 26ℓ/mm which is a factor of two increase in system resolution. More work is to be performed at higher resolutions as expected in practice.

HIGH FREQUENCY OIM

The partially coherent processes that have been applied to high frequency enhancement over the last three months has provided a large number of demonstratable results among laboratory prepared imagery. The process illustrates a contrast enhancement and a frequency dependent gain that is directed to enhance the high frequency components of imagery. At this time we are actively involved in emphasizing the application to operational imagery. To this end a large sample of images have been selected and will be processed when DP's are ready. One of the questions open at this time is the DP quality, relative to information on the ON, and also the optimum process for DP input to the OIM system. Based in availability of material we must assume that the DP is the original and enhancement is based on comparison with the DP. As we progress we will use DP information to aid in specifying best DP policy for OIM applications.

The characterization of the OIM system is now in progress with the use of sinusoidal targets. This information will provide us with knowledge on system response as related to the analytical predictions, and provide a basis from which system improvement can be measured and specified.

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Objective

Review of material & optics for planned program (see AS #23 etc.)

Cleaning & alignment performed.

Roll I Target Image of airfield,

On Pan-X. exp time in sec

Series 1.	1.1 D Filter	1/30	1/8	1/2	2	sec
2.	1.3 D	"	"	"	"	"
3.	1.5 D	"	"	"	"	"
4.	no filter	1/125	1/30	1/8	1/2	"

Results

Improvement ~~c~~ filters — seems that the image is poor compared to what we can see visually on the optical bench.

Roll II Same target

Source @ 1932 cm, filling about 3/4 of 4-mm dia. field.

Relay lens iris open.

Series 1.	1.3 D filter	1/8,	1/2,	2,	4	sec
2.	1.1 D "	"	"	"	"	"
3.	no filter	1/30,	1/8,	1/2,	1	"

Roll III Focus check!
(repeat of Roll II

Series 1.	1.3 D filter	1/8,	1/2,	2,	4	sec
2.	1.1 D "	"	"	"	"	"
3.	no filter	1/30,	1/8,	1/4,	1/2,	1 sec

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⇒ Note typical objects that we look at are less than about 50 μm cross-section. ~~For~~ 10" lenses then the angular subtense is $\frac{50}{250 \times 10^{-3}} = 0.0002$.

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Focus test
Target
25X1 [redacted] ing line "L" target
Objective
~~To determine if repetitive focusing accuracy attained. In dep. from magnification. Acc. only variable parameters have to be focused. This is to signif. focus is a variable.~~

Focus pos'n. → John C.
31.480 cm.

Roll I →

Exp. series
with filter, 4mm dia, 1.2D
(1) 1/8 sec. (7) 8 sec.
(2) 1/4 " (8) 16 sec.
(3) 1/2 "
(4) 1 "
(5) 2 "
(6) 4 "

Obj. This series will test ability to focus camera within system ... tolerance. This will test both John C + P.C. focus ability, as well as technique.

To record a series of images on one roll of film, const. input + exposure, each one after J.C. + P.C. focus.

① Re-Focus Position Tolerance

	ave	st. dev.
John C	31.54 cm	0.024 cm
Phil C	31.588 cm	0.010 "

② Resolution Tolerance c̄ Refocus

John C	89.5 l/mm	1.8 l/mm
Phil C	94.52 l/mm	4.2 "

② Based on average of P.C. + J.C. resolution readings of the 10 target images.

Data

Refocus

Bar group no.
a) J.C. read
b) P.C. "

Ave. resolution of a + b

		ⓐ	ⓑ	
J.C. refocus	#1	7-4	7-4	90.5 l/mm
	#2	7-4	7-4	90.5 "
	#3	7-4	7-4	90.5 "
	#4	7-4	7-4	90.5 "
	#5	7-4	7-3	85.5 "
P.C. refocus	#1	7-4	7-4	90.5 "
	#2	7-4~~6~~5	7-4	93.37 "
	#3	"	7-5	99.12 "
	#4	"	7-5	99.12 "
	#5	7-4	7-4	90.5 "

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Focus by

	John C.	corrected values of micrometer pos'n.		John C.	Phil C.	J.C. Focus ave readings
①	31.548	3m. .55	sleclip.	7.4	7.4	JC 90.5±9 PC 88.5±3
②	31.542	" .55	"	7.4	7.4	
③	31.581	" .58	"	7.4	7.4	31.576 ± .031
④	31.506	" .53	"	7.4	7.4	
⑤	31.516	" .51	"	7.4	7.3	PC Focus
⑥	BLANK	"	"			ave of readings
⑦	FOGGED	"	"	7.4	7.4	92 ± 93.1 ±
⑧	31.583	" .57	"	7.4	7.4	
⑨	31.573	" .59	"	7.4	7.5 7.5	
⑩	31.572	" .59	"	7.4		31.576 ± .004
⑪	31.574	" .60	"			
⑫	31.578	" .59	"	7.4	7.4	

PC

80.1
90.5
102

Res. values from imagery recorded

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① Note the consistent of individual results.

② Note also that resolution does not vary much over the variance of the positions taken.

What we did

Refocused 5 times each
Constant target, exp., proc.

	J.C.	P.C.	Resolution bar group
Pos'n	31.515 ± .011	31.5?? ± .04	
Res			

Re-Focus to best focus

	J.C.					P.C.					
Pos'n	31.578	31.542	31.581	31.506	31.516	31.583	31.573	31.572	31.574	31.578	
Resolution	7-4	7-4	7-4	7-4	7-4	7-4	7-4	7-5	7-5	7-4	

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Through focus run

Objective

#1 To determine depth of focus tolerance of the optical system + correlate with previous measurements of maintaining focus. If depth of focus is large compared to the variance in focus repeat, then we can consider focus a constant.

#2 To determine if refocus need not be performed. The transparency will be taken in + out, but kept a constant, and focus will be left at "best focus". We will thereby determine if we can consider focus a constant and not need to refocus.

Experiment #1 Through focus run

3 samples / position

1/8 acc. exp.

7 positions about 'best focus'

	Posn						
Roll 1	1	31.545	Con.	1/8,	1/2,	1/2,	fog
	2	31.560	"	"	"	"	"
	3	31.575	"	"	"	"	"
	4	31.590	"	"	"	"	blank, fog
Roll 2	5	31.605	"	"	"	"	"
	6	31.620	"	"	"	"	blank, fog
		31.635	"	"	"	"	"

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Experiment #2
Maintain focus at 31.590 cm.
To test that transparencies can be placed into system without altering focus.
Transparency will be returned to same position at each time.

Trans. removal & replacement

Roll 3

#1	1/8 clr,	1/8,	1/8,	fog
#2	"	"	"	"
#3	"	"	"	"
#4	"	"	"	"
#5	"	"	"	"

Roll #2 data

P.C. data reading (reading of horiz. line groups using right edge of target)

	bar group/resolution (1)	(2)	(3) repeats	
Position 31,575	7-4 90.5 l/mm	7-4 90.5	7-4 90.5	Roll 1
31.560	7-4 90.5	7-4 90.5	7-4 90.5	
31.575	7-5 102 l/mm	7-4 90.5	7-4 90.5	
31.590	7-4 90.5	7-5 102	7-5 102	
best focus 31.605	7-5 102	7-5 102	7-5 102	
31.620	7-5 102	7-5 102	7-4 90.5	Roll 2
31.635	7-3 80.6 l/mm	7-3 80.6	7-3 80.6	

Film process

HC 110 - dilution 'B'
68°
5 min

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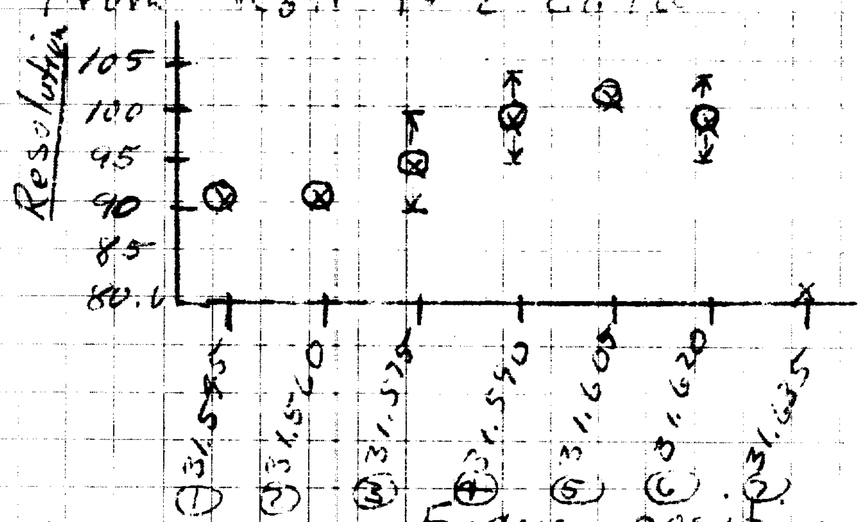
Roll 2 Data

Bar group/resolution @ 31.590

Steps of removal & replacement	①	②	③	
#1	7-4 90.5	7-4	7-4	Ave.
#2	7-5 102	7-4	7-4	7-4
#3	7-4 90.5	7-4	7-4	
#4	7-4 90.5	7-4	7-4	
#5	7-4 90.5	7-4	7-4	

Focus Res. vs. Position
From Roll 1 & 2 data



	Ave.	σ
①	90.5	0
②	90.5	0
③	99.3	5.3
④	98.2	5.3
⑤	102	0
⑥	98.2	5.3
⑦	80.1	0

Conclusion
① No focus change when transparency is replaced.

② Focus tolerance (Depth of focus)
31.575 to 31.620
or 31.598 ±.022 cm

Student's Name Date [illegible]

Subject Instructor's Name

Photographs of the [illegible] targets processed to [illegible] gamma [illegible] with [illegible] ([illegible]). Gamma and modulation of the [illegible] will have to be measured using a given densitometer [illegible]. Since the system [illegible] (S4(U)A) [illegible] [illegible] [illegible] the [illegible] of the [illegible] is to be [illegible] correctly.

First generation [illegible] of the target were processed in [illegible] (XS [illegible] at 1:2 [illegible] contrast [illegible] to [illegible]). Exposure [illegible] using the [illegible] type [illegible] 20 [illegible].